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(71)(72) Applicant and Inventor: KLINGE, Erwin, Ludwig [GB/GB]; Hamilfield House, Beith, Ayrshire KA15 2JQ (GB).

(74) Agent: PACITTI, Pierpaolo, A., M., E.; Murgitroyd and Company, 373 Scotland Street, Glasgow G5 8OA (GB).

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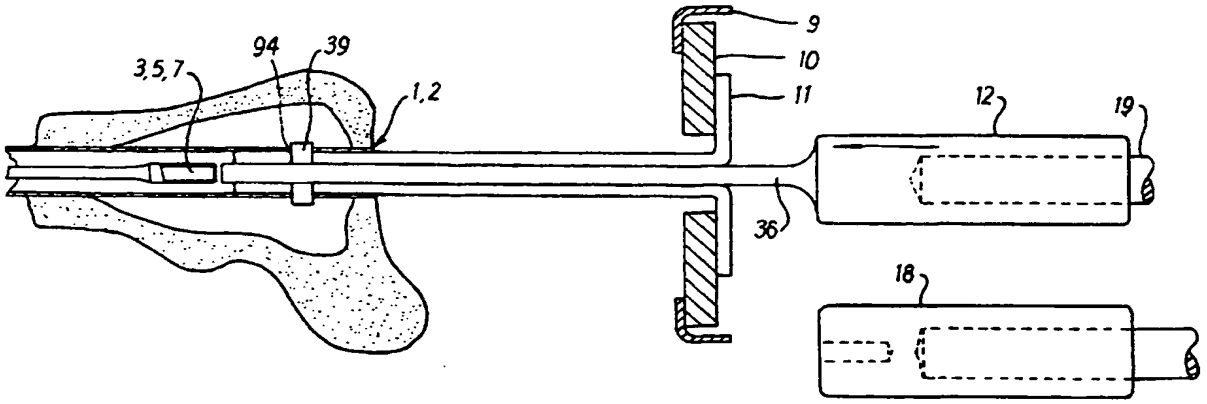

(57) Abstract

An intramedullary nail (1) is expandable along its entire length enabling it to be inserted inside a broken bone in its non-expanded form and then expanded so as to secure the bone. Such insertion can be performed without drilling into the bone and the securing of a bone using such a nail alleviates the need for subsidiary pins or nails, thus reducing operation time. Such a nail may consist of a hollow tube with broken cross section which may be expanded by forcing an insert into the break in cross section thus prising it apart.

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Expanding Intramedullary Nail

The present invention relates to an expanding intramedullary nail for uniting bone fragments and to apparatus for operating the nail.

Conventionally, nails and fixing pins for bone fractures require the bone to be drilled out before the nail or pin can be inserted. This results in loss of tissues which are important for bone growth and healing and can result in fat embolism while drilling. Known devices comprise hollow sleeves accommodating mechanisms, typically for extending flukes to anchor the pin on the inside of the bone.

One of the disadvantages encountered with known devices is that once the nail or pin is *in situ* it cannot easily be removed; this can cause serious problems if a nail or pin becomes stuck before reaching its final position. Such nails may also need holding in place by other nails, necessitating long operations and sometimes additional operations specifically to insert or remove the subsidiary nails.

According to the present invention there is provided

apparatus for pinning one or more bone elements comprising an intramedullary nail which is selectively cross-sectionally expandable along substantially its entire length, an expander for said nail and operating means for operating said nail in conjunction with said expander.

Preferably, the nail is elongate and hollow.

Preferably, the nail is expandable *in situ* within a bone.

Preferably, the nail has a broken cross section along substantially its entire length and is expandable by enlarging the break in the cross section.

The nail may be configured so as to be enlargeable by an expander in the form of an elongate insert, inserted into the hollow portion of the nail, where said insert comprises a plurality of elongate members having adjacent cooperating surfaces and configured such that relative axial movement of the elongate members results in their non cooperating surfaces being forced away from each other producing an increase in the total effective cross section of the insert.

Alternatively, the break in the cross section may be configured so as to accommodate the insertion of an expander or a selected one of a plurality of expanders, each expander being in the form of an elongate member, insertion of said expander prising open the break in the cross section by an amount determined by the size and shape of the expander and each expander having a portion configured so as to be engageable by an expander insertion and/or extraction means.

Preferably, the elongate expander has a shaped portion configured to engage a portion of the inside surface of the intramedullary nail configured to have a complementary shape.

Preferably, there is provided apparatus for expansion and/or reversing said expansion, of the nail comprising engaging means which engage the nail and means for applying or releasing a force to or from said nail.

Preferably, said apparatus is for insertion and/or extraction of an expander comprising a push and/or pull member which engages the expander, a forcing means which provides force to the push and/or pull member and nail engaging means which helps reduce movement of the nail relative to said apparatus.

The forcing means may comprise a screw jack mechanism, ratchet mechanism or other substantially non-percussive mechanism.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1a is a cross-section of an embodiment of an expanding intramedullary nail and a portion of an apparatus for insertion of an expander insert in accordance with the present invention;

Fig 1b is a cross-section of an embodiment of an expanding intramedullary nail and a portion of an apparatus for withdrawal of the expander insert in accordance with the present invention;

Fig 2a and Fig 2b are cross-sections corresponding to Figs 1a and 1b of an alternative embodiment;

Figs 3a-3f are cross-sections of the expanding intramedullary nail of Fig 1 and expander insert in accordance with the present invention;

Figs 4a-4e are cross-sections of an embodiment of an intramedullary nail and expander inserts, alternative to those shown in fig 3a-3f. Fig 4f is a further embodiment of an intramedullary nail;

Fig 5a and Fig 5b are side views of an apparatus for operation of an expanding intramedullary nail in accordance with the present invention; the apparatus of Fig 5a is for insertion and the apparatus of Fig 5b for withdrawal of an expander insert;

Figs 6a, 6b, 7a, 7b, 8a and 8b are side and frontal views showing alternative embodiments of apparatus for operation of an expanding intramedullary nail, in accordance with the present invention;

Figs 9a, b and c are a broken side view, end view and top view respectively of an intramedullary nail in accordance with the present invention;

Figs 10a and b are side and end views of an alternative embodiment of an intramedullary nail in accordance with the present invention;

Figs 11a, b and c, are side, end and top views respectively of an expander of the apparatus of

Fig 1a, 1b, 2a or 2b;

Figs 12a and 12b show side and end views, respectively of an expander of the type illustrated in Figs 4a-4e;

Figs 13a and 13b show an alternative form of expander insert;

Fig 14 shows a preferred embodiment of apparatus similar to the apparatus of Figs 6a,b;

Figs 15a, b show a push member for use with the apparatus of Fig 14;

Figs 16a,b show a pull member for use with the apparatus of Fig 14; and

Fig 17 shows a cross section of an intramedullary nail which incorporates a locking mechanism and could be used with the expander of Figs 13a,b.

Referring to the drawings a first embodiment or embodiments of the present invention shall be presented with reference to Figs 1a, b, 2a, b, 3a-f, 5a,b, 9a-c, and 11a-c. Thereafter further alternative embodiments shall be described with reference to Figs 4a-f, 6a,b, 7a,b, 10a,b 7a,b, 12a,b, 13a,b, 14 and 15a,b.

The first embodiment of the present invention comprises an expandable nail 1 in the form of an elongate tube having a longitudinal slit 30 in the tube wall 31. The expandable nail 1 has a number of expander inserts 3, 5, 7 to give a range of degrees of expansion. Each expander insert 3, 5, 7 is formed of an elongate member

40 with a screw-threaded attachment end member 41. The elongate member 40 is of generally rectangular cross-section 42 with each expander insert 3, 5, 7 having a different width of a first portion 37 of the rectangular cross-section 42, which portion 37 corresponds when *in situ*, with the longitudinal slit 30 of the expandable nail 1 (Fig 8c). Six expander inserts 3, 5, 7 are illustrated in Fig 3a to 3f with variable widths of first portion 37 of the rectangular cross-section 42, the widths of the first portion 37 vary from 1 to 3.5 mm.

An expander insertion device 32 has a push rod 12, two draw bars 11, a thrust plate 9, 13 or 14 and a modification to the thrust plate 10. The push rod 12 has a thin elongate member 36 a first end of which is attachable to the end member 41 of the expander insert 3, 5 or 7, while a second end of the push rod 12 has an attachment sleeve 16 for attachment of a push rod extension 22.

The insertion device 32 has a sprung ratchet tool 34, attached to an end plate 21 orthogonally situated around the push rod extension 22. The ratchet tool 34 is manually operable by means of a handle 38. The end plate 21 is connected to the thrust plate 9 by two tie rods 20, 23 which are disposed on either side of the push rod 12 and push rod extension 22. The thrust plate 9 and end plate 21 have centrally disposed apertures through which the push rod 12 and push rod extension 22 are situated. The ratchet tool 34 is placed against the end plate 21 and pushes the push rod 12 linearly along the longitudinal axis of the push rod 12 towards the expandable nail 1.

The draw bars 11 comprise elongate members each having a first end with a transverse pin 39 for location of the draw bar 11 in a fixed position to the expandable nail 1. The pin 39 is situated a short distance from the first end of the draw bar 11 and attached to the proximal end of the expandable nail 1 by engaging a hole 94 in said nail 1. Figs 3a to 3f show a cross-section of the pins 39 of the draw bars 11 and the expandable nail 1. The draw bars 11 and pins 39 are locked into place with respect to the nail 1 by insertion of the push rod 12, 36 between the two draw bars 11.

A short distance from the second ends of the two draw bars 11, the elongate members bend through 90°. These orthogonal portions of the elongate members project from the longitudinal axis of the push rod 12. The thrust plate 9 and modification 10 are disposed around the draw bars 11 and the push rod 12 such that the orthogonal portions of the draw bars 11 are adjacent to the thrust plate modification 10 on the opposite side of the thrust plate 9 to the expanding intramedullary nail.

An expander extraction device has a pull rod 15 which is attachable to the end of the expander insert 41 within the expandable tube 1. The pull rod 15 has a diameter such that it fits closely within the expandable nail 1. Two pull rods 15, 24 may be connected by means of a screw threaded sleeve 16. A withdrawal thrust plate 13, 14 is positioned against the proximal end of the expandable nail 1 and the thrust plate 13, 14 has a central opening through which the pull rod 15, 24 is positioned. The sleeve 16 is positioned on the opposite side of the thrust plate 13,

14 to the expandable nail 1.

The expander extraction device 33 has a sprung ratchet tool 35 attached to an end plate 25 situated orthogonally around the pull rod 15, 24. The end plate 25 and thrust plate 13, 14 are connected by two tie rods 20, 23 which are disposed on either side of the pull rod 15, 24. The end plate 25 and thrust plate 13, 14 have centrally disposed apertures through which the pull rod 15, 24 is situated. The ratchet tool 35 is adjacent to the end plate 25 and pulls the pull rod 15, 24 linearly along the longitudinal axis of the pull rod 15, 24 away from the expandable nail 1.

In use, the expanding intramedullary nail in its unexpanded form is positioned in its desired position inside a bone along the axis of the bone thereby joining any fracture in the bone.

The expandable nail 1 is between 8 and 12 mm in diameter depending on the dimensions of the bone and approximately 320 mm long with a minimum wall thickness of 0.5 to 1.0 mm. Intramedullary nails in accordance with the present invention may be of any of a variety of sizes according to the dimensions of the bone.

The expander insert 3, 5, 7 is inserted into the expandable nail 1 such that the expandable nail 1 expands along its whole length. The expander insert 3, 5, 7 is inserted with the first portion 37 of the expander insert 3,5,7 corresponding to the longitudinal slit 30 of the expandable nail 1, situated in the slit 30. The expandable nail 1 is forced to expand as the width of the first portion 37 of the expander insert is greater than the natural width of the slit 30 in its

unexpanded form. The degree of expansion of the expandable nail 1 can be controlled by choice of the appropriately sized expander insert as shown in Fig 3a to 3f.

The expander inserts 3, 5, 7 are pushed into the expandable nail 1 by use of an expander insertion device 32. The device is arranged as described above such that the action of the sprung ratchet tool 34 can be manually operated by means of a sprung handle 38. Each operation of the handle 38 pushes the push rod 12, 22 a discrete distance along the direction of the push rod's 12, 22 longitudinal axis such that it pushes the expander insert into the expandable nail 1.

The ratchet tool 34 is fixed to the end plate 21 by a weld or braze to a frame projecting from the end plate 21. The thrust plate 9 is held a fixed instance from the end plate 21 by the connecting tie bars 20, 23 between the plates 9, 21. The draw bars 11 have orthogonal portions situated on the opposite side of the thrust plate 9 to the expandable nail such that the pushing action of the ratchet tool 34 is relayed to the push rod 12 and the expander 3, 5, 7 and does not move the expandable nail 1.

When the selected expander is fully inserted into the expandable nail 1, the insertion device 32 can be removed. The expander can remain in position until such time as the expansion of the nail is to be reversed, that is, just prior to its repositioning or removal from the bone. The expander extraction device can be positioned with a pull rod 15, 24 attached to the expander insert 3, 5, 7 within the expandable nail 1. The thrust plate 13, 14 is positioned against the

proximal end of the expandable nail 1 and held in fixed connection with the end plate 25 by tie rods 20, 23. The ratchet tool 35 for withdrawal is fixed to the end plate 25 as described for the ratchet tool 34 for insertion. Each operation of the sprung ratchet tool 35 is manually operated by means of a sprung handle 38, pulling the pull rod 15, 24 a discrete distance along the longitudinal axis of the pull rod 15, 24 out of the expandable nail 1.

On withdrawal of the expander insert 3, 5, 7 the extraction device 33 can be removed.

Once the expander has been removed, the nail, being made from a resilient material, is allowed to revert to approximately its unexpanded size and shape and can be removed and used again or repositioned if necessary. Thus problems encountered when a nail is wrongly positioned or obstructed before reaching its final position are overcome.

One form of expandable nail can accommodate a range of sizes of bone and fracture although various sizes of nail would be used according to the circumstances. No drilling of the bone is necessary as the insertion device 32 slowly pushes an expander insert 3, 5, 7 into the expandable nail 1. The nail itself can be positioned manually prior to expansion without drilling because it need only be forced through relatively soft medullary tissue.

The expandable nail 1 and the expander inserts 3, 5, 7 are made of a titanium alloy and all the other components of the apparatus are made of stainless steel except the end plates 25, 21 which are made of mild

steel.

Further embodiments of the present invention will now be described.

Fig 4a-e shows an alternative cross-sectional configuration for an intramedullary nail and a series of expander inserts to that shown in Fig 3a-f.

The cross section of the nail of this embodiment is not circular but is configured so as to slidingly engage a shaped portion of the expander insert, as the expander is inserted into or withdrawn from the nail.

This alternative configuration gives greater stability of position of the expander insert as it moves relative to the nail, and also helps prevent rotation of the nail with respect to the bone.

Fig 4f shows a slightly differently shaped, but functionally similar intramedullary nail to those shown in Figs 4a-e.

Figs 6a,b, 7a, b and 8a, b show side views (6a, 7a, 8a) and front views (6b, 7b, 8b) of alternative expander insertion/extraction devices 600, 700, 800 to those shown in Fig 5a,b.

Each of the devices has a similar structure to the devices of Figs 5a, b except that a screw jack mechanism is used in place of the ratchet mechanism and that power can be provided either manually by turning a handle 601 or by an electric motor which is supplied by a lead 704, 804 or possibly battery operated (not shown). Other methods of providing a force, such as

hydraulics could also be used.

Fig 6b shows an expander insertion/extraction device 600 having two handles 601, 602 and a threaded rod 603 which, when rotated, acts as a screw jack mechanism providing a controllable force for the insertion of an expander into, or extraction of an expander from, an intramedullary nail. The device includes a rear end plate 621 and a front end plate 609 which are connected by tie rods 620, 623. The rear of the threaded rod 603 passes through a threaded aperture in the rear end plate 621 and attaches rigidly to a handle 601 such that rotation of the handle 601 also rotates the threaded rod 603 and controls its movement through the aperture in the end plate 621 thus controlling the length of the threaded rod which extends from the rear end plate 621 towards the front end plate 609.

The threaded rod 603, at its end nearest the front end plate 609, engages a thrust plate 608 which moves along the tie rods 620,623, that is in a substantially straight line between the front end plate 609 and the rear end plate 621. The thrust plate 608 engages a push/pull member 624 which passes through an aperture in the front end plate 609 and attaches to the expander which is to be forced.

Thus in use, rotation of the handle 601, which can be performed manually, results in a force, in an axial direction according to the direction of the rotation, on the expander.

The expander insertion/extraction devices shown in figs 7a and 8a, 700, 800 respectively, work in a similar manner to the device 600 and will thus not be described

in detail. Corresponding parts of each of the three devices are denoted by three figure numerals in which the first digit denotes the device and the latter two digits are common.

Two of the devices 700,800 are shown as being operated by an electric motor supplied by a flex 704,804. Thus the handles 701,801 do not rotate and the screw threaded rod does not attach to the handle 701,801 but is driven by the electric motor via transmission components in the housing 770,870.

The two electrically driven devices 700,800 are operated by use of buttons 750,851,852 located on a handle of the device. One of the devices 800 is shown as having two buttons 851,852 one corresponding to each direction of rotation of the threaded rod.

The front views of the devices show a vertical member 690, 790, 890. This member is for use in attaching the push/pull member to the expander. As an alternative to the screw portion 3 of the expander 40, an expander could be configured with an aperture adjacent to one end of said member as shown in Figure 12. In use the member 690,790,890 passes through the aperture thus securely engaging the expander.

In Figs. 6a, 7a and 8a the nail extends a distance outside the bone while it is being expanded. Having a portion of the nail extending from the bone has benefits over inserting it so that it is entirely contained within the bone, in that it prevents or reduces the growth of callus over the nail and also facilitates subsequent removal of the nail from the bone.

Fig 10 a,b shows an alternative embodiment of an expandable intramedullary nail to that shown in Fig 9 a,b,c. The cross sectional shape, shown in Fig 10b, is not round but is shaped to help prevent rotation of the nail relative to the bone and also to help guide a suitably shaped expander into or out of the nail. It can also be seen from Fig 10a that the break in cross section 1030 is flared, widening towards the end where an expander would be inserted. This facilitates the initial insertion of the expander. The end which would be foremost when the nail is inserted into a bone is shaped without sharp corners in order to prevent catching on the inside of the bone and facilitates insertion of the nail into the medullary cavity.

Fig 12a shows a side view and Fig 12b shows an end view of the type of expander illustrated in Fig. 4. An aperture 1201 is provided as a means of attachment to an insertion or extraction device as described above.

Figs 13a, b show a further embodiment of an expander for an expanding intramedullary nail comprising two longitudinal sections 1305, 1306 which have teeth with corresponding angled surfaces. The angled surfaces of the teeth are arranged such that a force applied to a first end 1309 of one of the longitudinal sections 1302, causing it to move in an axial direction relative to the other longitudinal section 1301, results in angled surfaces of the teeth 1303,1304 moving against each other and gradually disconnecting as shown in Fig 13b, causing corresponding motion of the sides of the expander 1305,1306, away from each other.

In use the expander insert is inserted in its unexpanded form into the intramedullary nail (not

shown). Apparatus (not shown) would be provided to force the longitudinal sections 1301, 1302 to move axially relative to each other. Such apparatus might comprise a device such as shown in any one of Figs 5-8 with the addition of an attachment means to prevent movement of the longitudinal section of the expander insert which is to remain stationary. Thus the longitudinal sections would be forced to move relative to each other thereby causing the expansion of the expander insert as detailed above.

The expander insert, on expansion, forces the intramedullary nail to expand with the break in cross-section widening to accommodate the expander insert.

Use of an expander of this type requires a locking mechanism either on the expander itself, or on the nail. Such a locking mechanism would be necessary to maintain the nail in its expanded state. A locking mechanism on the expander would require the expander to be left in the nail for as long as the expanded state is required. If the locking mechanism were on the nail the expander could be removed leaving the lock expanded nail *in situ* in the patient's bone.

Fig 14 shows a preferred embodiment of an expander insertion/extraction device 1400 similar to that shown in Fig 6.

In this embodiment there is a threaded rod 1403 which is hollow and contains a solid rod 1404 which extends through a thrust plate 1408. The solid rod 1404 is attached to a push/pull member 1461 by a locking device 1478 which provides two pins 1479, 1480 one of which passes through the solid rod 1404 and of one which

passes through the push/pull member 1461. The solid rod 1404 is secured to the thrust plate 1408 by a pin. This arrangement gives secure connection of the threaded rod 1403 to the thrust plate 1408 and push/pull member 1461/1462 during both insertion and extraction procedures.

The expander insertion/extraction device also includes two pins 1439, which, in use, engage apertures in an intramedullary nail 1401 in order to secure the device to the nail. The pins 1439 are attached to members 1440 which engage the outside of the nail 1401, thus differing from the arrangement shown in Figs 1a, 2a and greatly facilitating the insertion of the pins 1439 into the apertures. The pins 1439 are secured in the apertures by a circlip 1474 which forces the members 1440 against the outside of the nail 1.

Push and pull members 1461,1462 for use with the device of Fig 14 are shown in Fig 15a,b and 16a,b respectively.

The push member 1461 consists of a rod which has one end portion configured for attachment to the solid rod 1404 via the locking device 1478 and the other end portion configured for engaging, and applying a pushing force to, an expander.

A pull member 1462 consists of a rod similar to the push member 1461 except that the end portion which engages an expander is configured for the application of a pulling force.

The portion of the push member 1461 or pull member 1462 configured to be attached to the solid rod 1404 of the

insertion/extraction device 1400 comprises a flattened part with an aperture. The aperture, in use, engages the pin 1479 which is provided by the locking device 1478.

The portion of the push member 1461 configured to engage the expander comprises a slot into which a portion of the expander fits.

The portion of the pull member 1462 configured to engage the expander comprises a hook shaped member which, in use, passes through the aperture 1201 of an expander such as that shown in Fig. 12a.

Fig. 17 shows a cross section of an intramedullary nail according to the present invention which incorporates a locking device such that it could be suitable for use with the expander insert shown in Figs 13a,b.

The nail comprises a cylindrical tube 1700 with a break in cross section 1704 and a pair of members 1705,1706 extending from either side of the break in cross section into the interior of the cylindrical tube 1700. The members 1705,1706 are curved or bent, and configured such that expansion of the tube by increasing the size of the break in cross section causes at least some portions of the members to move longitudinally against each other. The portions of the members which move against each other are each equipped with teeth with inclined surfaces configured such that motion of the members 1705,1706 against each other in the direction that corresponds to expansion of the tube 1100 is possible, but motion in the opposite direction is prevented for as long as the teeth 1703 on the two members 1705,1706 engage each other.

The two members 1705,1706 include portions 1707,1708 spaced apart from each other. These spaced portions 1707,1708 are parallel to and proximate to the toothed portions.

The two members 1705,1706 are configured such that the toothed portions are aligned substantially orthogonal to a radius of the cylindrical tube 1700 that crosses the break in cross section 1704. The members 1705,1706 are also configured so as to allow an expander 1701 of the type shown in Fig 13 to be inserted into the cylindrical tube 1700 and occupy a diameter of the tube substantially parallel to the toothed portions of the members 1705,1706.

In use the tube 1700 is inserted in its unexpanded form into the medullary cavity of the bone to be secured. An expander 1701 of the type shown in Figs 13a,b and described above is then inserted into the hollow portion of the tube 1700.

An operating means (not shown) is then used to operate the expander 1701 and thus expand the tube by the desired amount. As the tube 1700 expands, the teeth 1703 on the members 1705,1706 slide over each other.

When the desired expansion of the tube has been obtained the expander may be returned to its original configuration (as shown in Fig 13a) and the nail remains expanded, unable to return to is expanded state because of the engaging teeth 1703 on the members 1705,1706. The operating means and expander 1701 can thus be removed from the proximity of the nail leaving the nail in its expanded form.

When the expansion of the nail is to be reversed an elongate member can be inserted into a space, 1702, formed by the spaced apart portions 1707,1708 of the members 1705,1706. Insertion of the elongate member, which is dimensioned to be slightly larger than the natural distance between the spaced apart portions 1707,1708 of the members 1705,1706, forces the spaced apart portions 1707,1708 away from each other thus disengaging the teeth and allowing the tube 1700 to revert to its unexpended form.

Improvements and modifications may be incorporated without departing from the scope of the invention.

CLAIMS

1 Apparatus for pinning one or more bone elements comprising an intramedullary nail being selectively cross-sectionally expandable along substantially the entire length of the nail, an expander for said nail, and operating means for operating said nail in conjunction with said expander.

2 An intramedullary nail being selectively cross sectionally expandable along substantially the entire length of the nail.

3 A nail as claimed in Claim 2 wherein the nail is hollow and elongate.

4 A nail as claimed in either of Claims 2 or 3 wherein the nail is expandable *in situ* within a bone.

5 A nail as claimed in any one of Claims 2 to 4, wherein the nail has a broken cross section throughout substantially its entire length and is expandable by enlarging the break in the cross section.

6 A nail as claimed in any one of Claims 3 to 5, wherein the nail is configured so as to be enlargeable by an expander in the form of an elongate insert, inserted into the hollow portion of the nail.

7 A nail as claimed in Claim 5 wherein the break in cross section is configured so as to accommodate

the insertion of an expander or successive insertion of a plurality of expanders, each expander being in the form of an elongate member.

8 An expander for use in the apparatus of Claim 1, comprising a first portion for engagement of an intramedullary nail and a second portion configured to be engaged by an operating means for said nail and expander.

9 An expander as claimed in Claim 8 wherein the expander is in the form of an elongate insert for insertion into a hollow portion of an expandable intramedullary nail.

10 An expander as claimed in Claim 9 wherein the elongate insert comprises a plurality of elongate members having cooperating surfaces and configured such that relative axial movement of the members results in their non-cooperating surfaces being forced away from each other effecting an increase in the total cross section of the insert.

11 An expander as claimed in Claim 8 or 9 wherein the first portion is insertable into the break in cross section of the nail of Claim 5, and is adapted to prise open the break by an amount determined by the size and shape of the expander, and the second portion is configured so to be engageable by an expander insertion/extraction means.

12 An expander as claimed in Claim 11 having a shaped portion configured to engage a portion of the inside surface of an intramedullary nail

configured to have a complementary shape.

13 Operating means for use with an intramedullary nail, said nail being expandable along substantially its entire length, comprising engaging means which engages the nail and means for applying or releasing a force to or from said nail.

14 Operating means as claimed in Claim 13, being adapted for the insertion and/or extraction of an expander, comprising a push and/or pull member adapted to engage the expander, forcing means which provides force to the push and/or pull member and nail engaging means, which in use, braces the nail against the operating means.

15 Operating means as claimed in Claim 13 or 14 wherein the forcing means comprises a screw jack mechanism, ratchet mechanism or other substantially non-percussive mechanism.

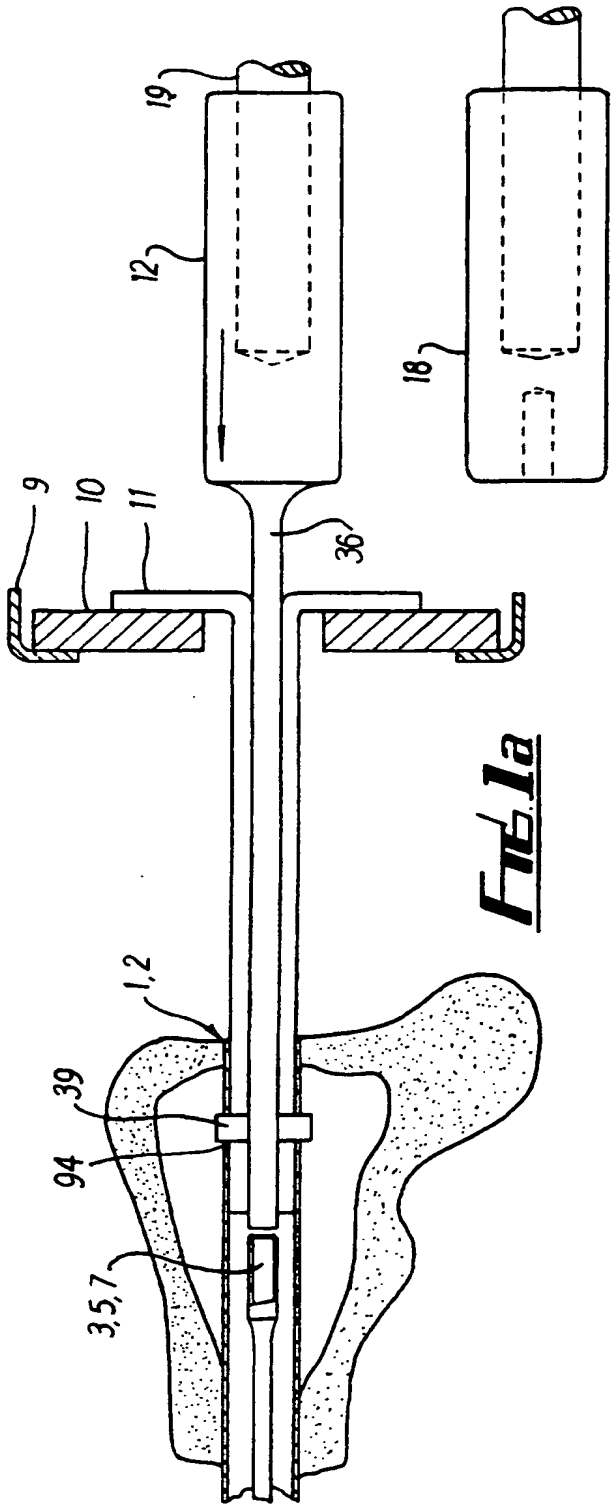

Fig. 1a

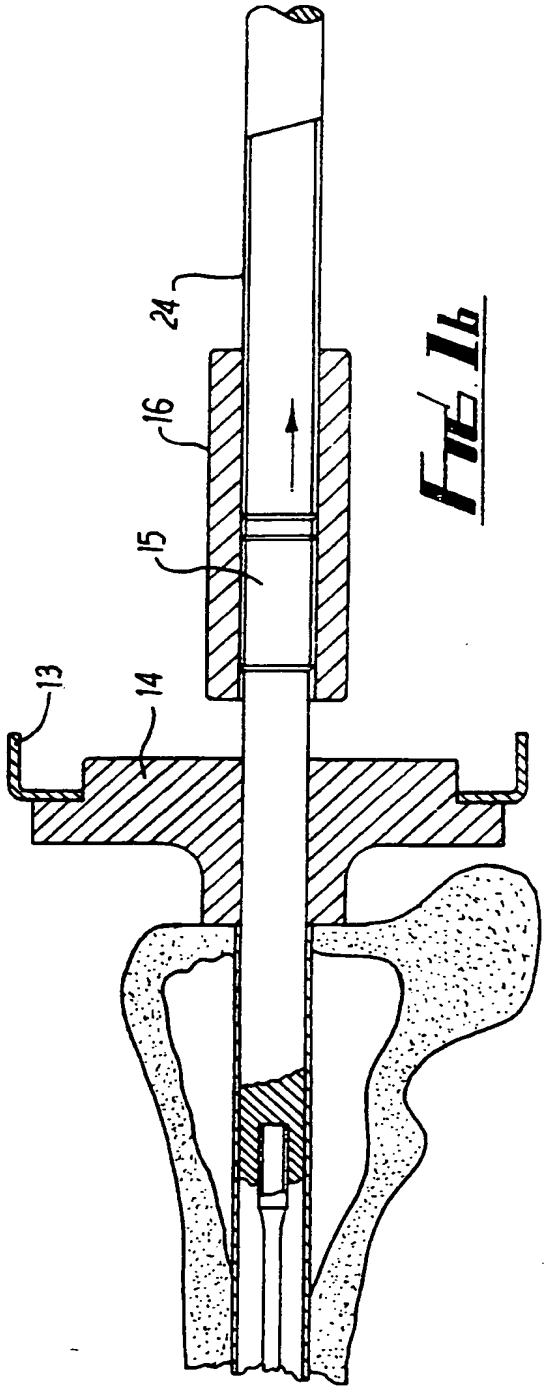

Fig. 1b

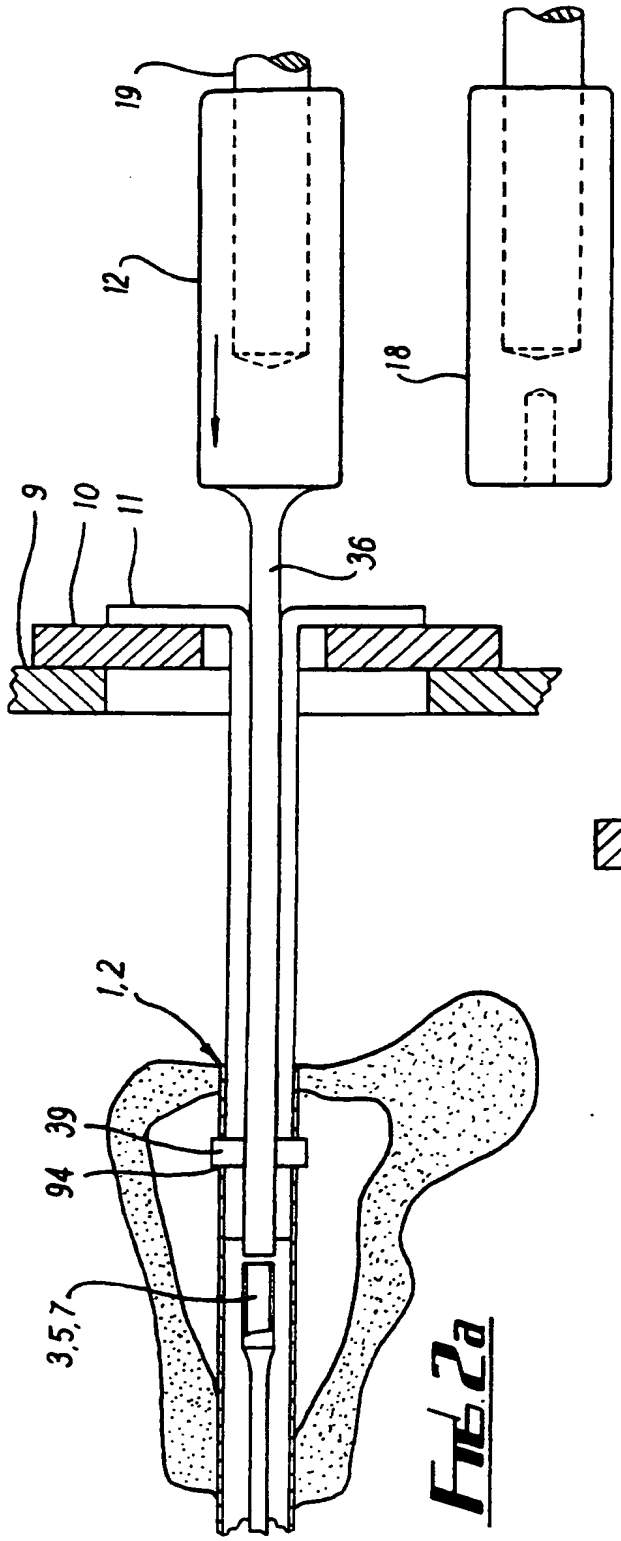

Fig.2a

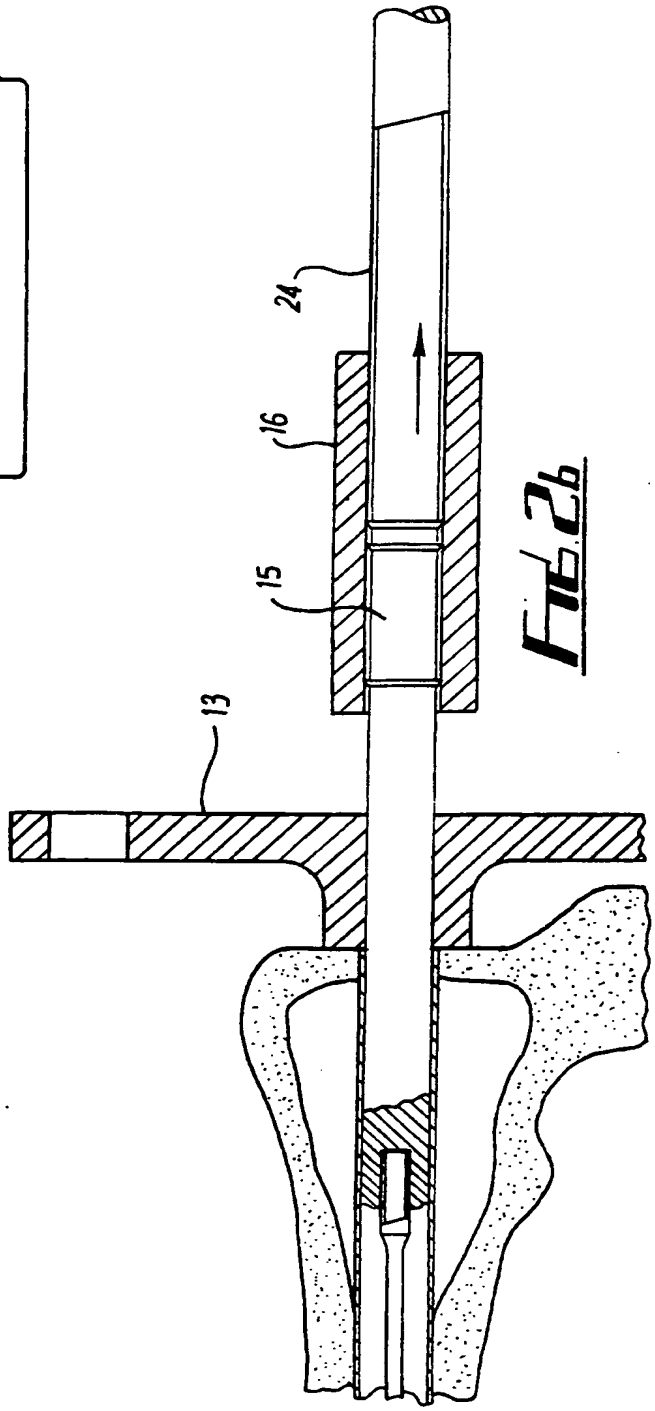

Fig.2b

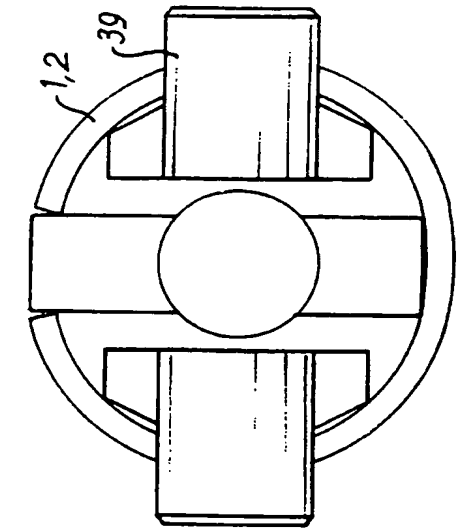

Fig. 3c

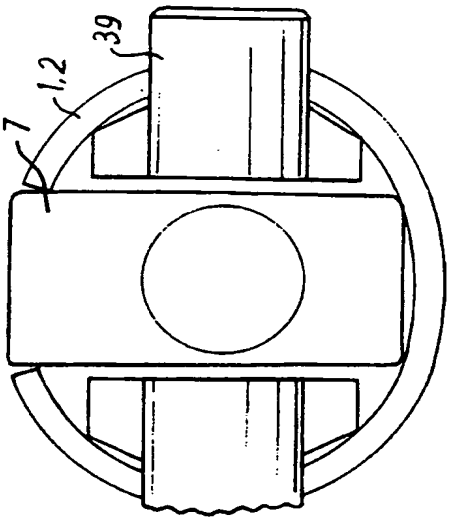

Fig. 3f

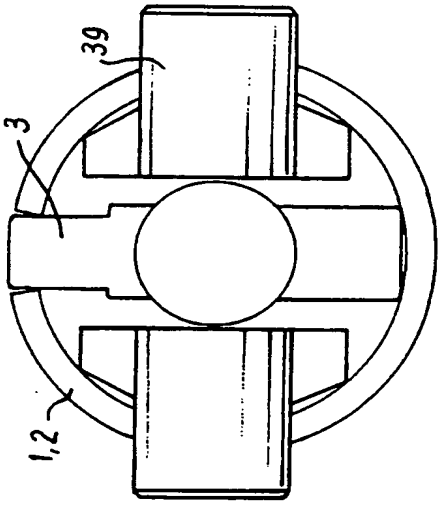

Fig. 3b

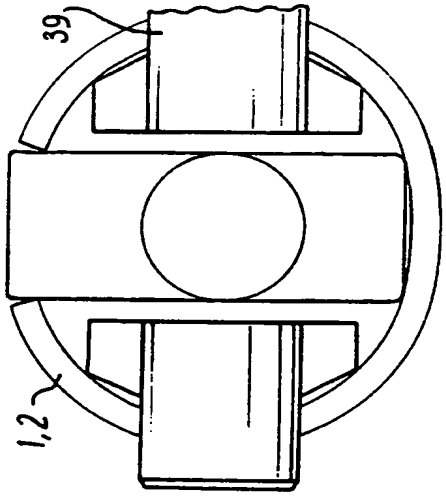

Fig. 3e

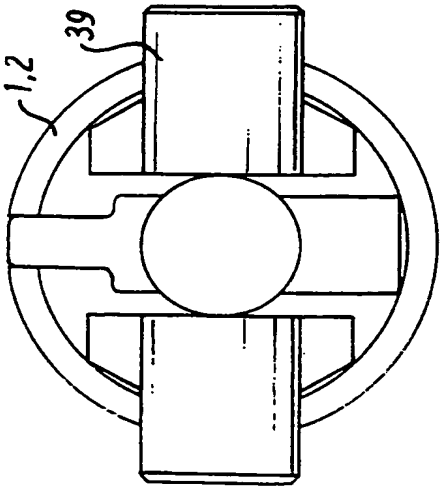

Fig. 3a

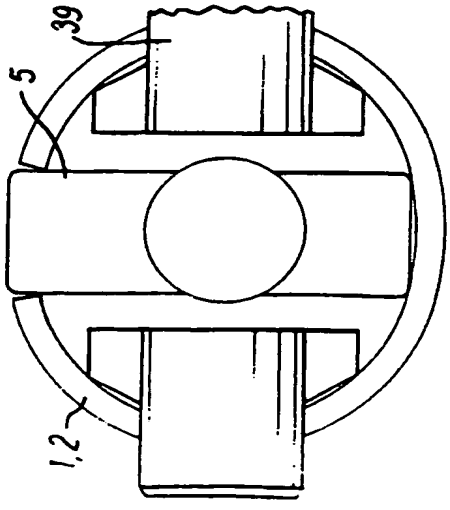

Fig. 3d

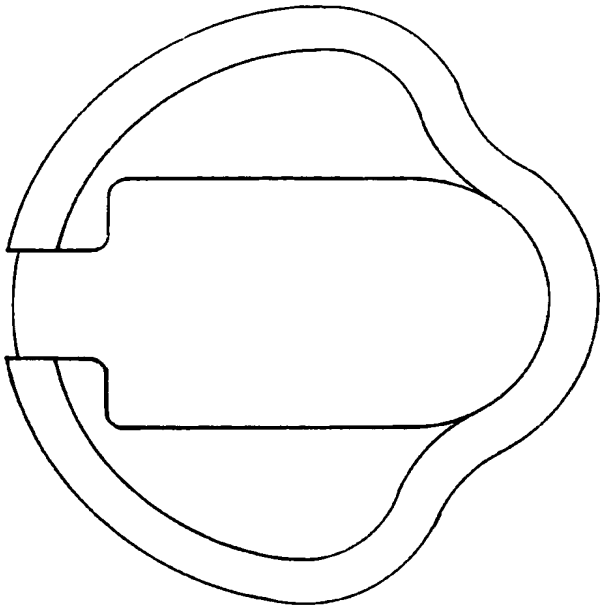

Fig 4b

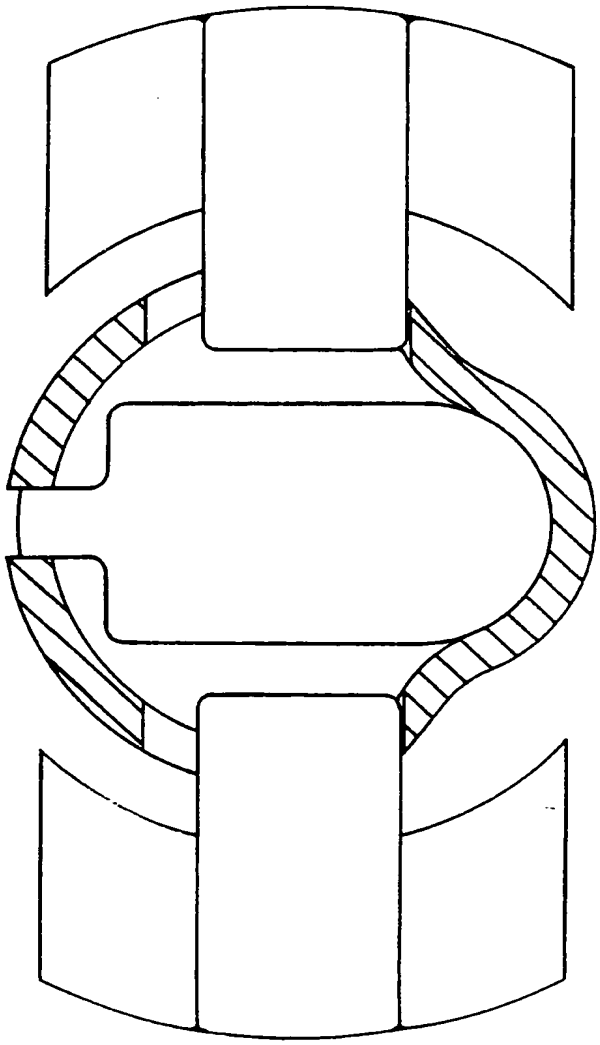

Fig 4a

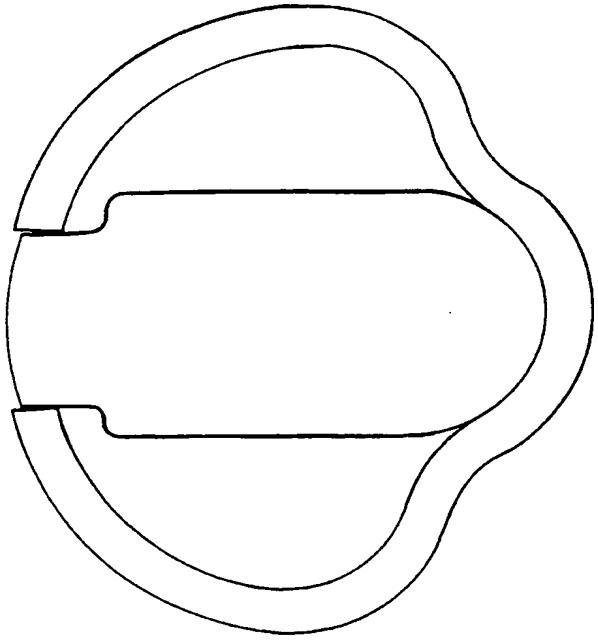

Fig. 4d

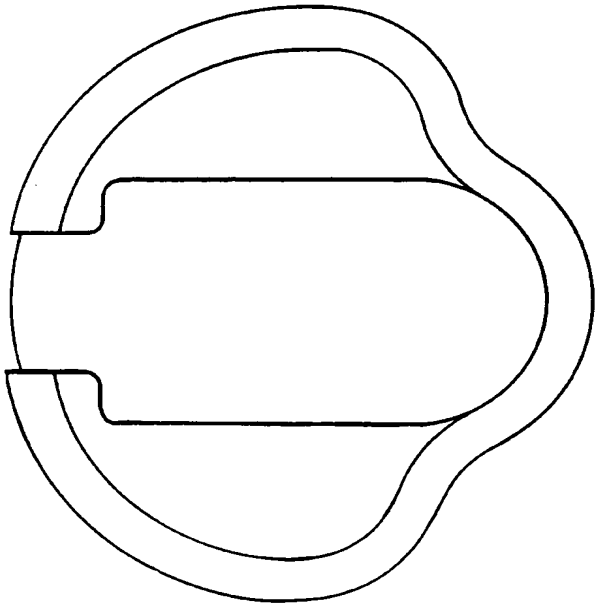

Fig. 4c

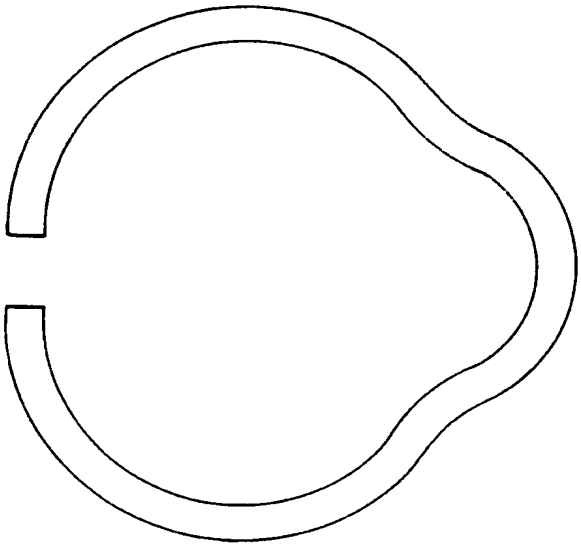

FIG. 4f

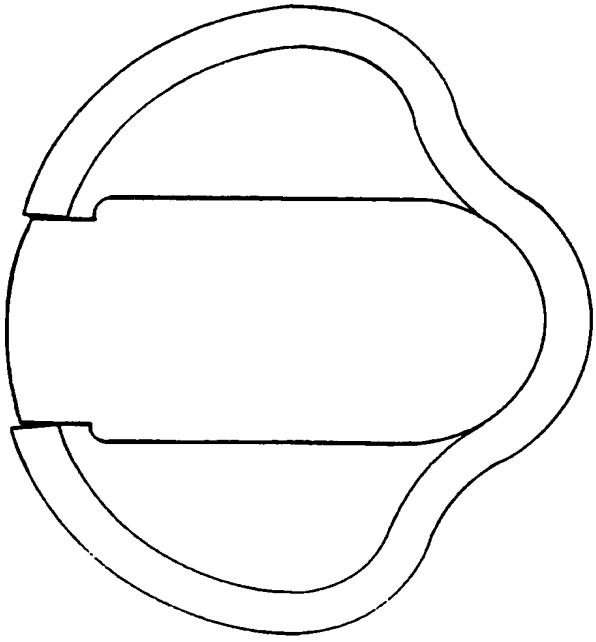

FIG. 4e

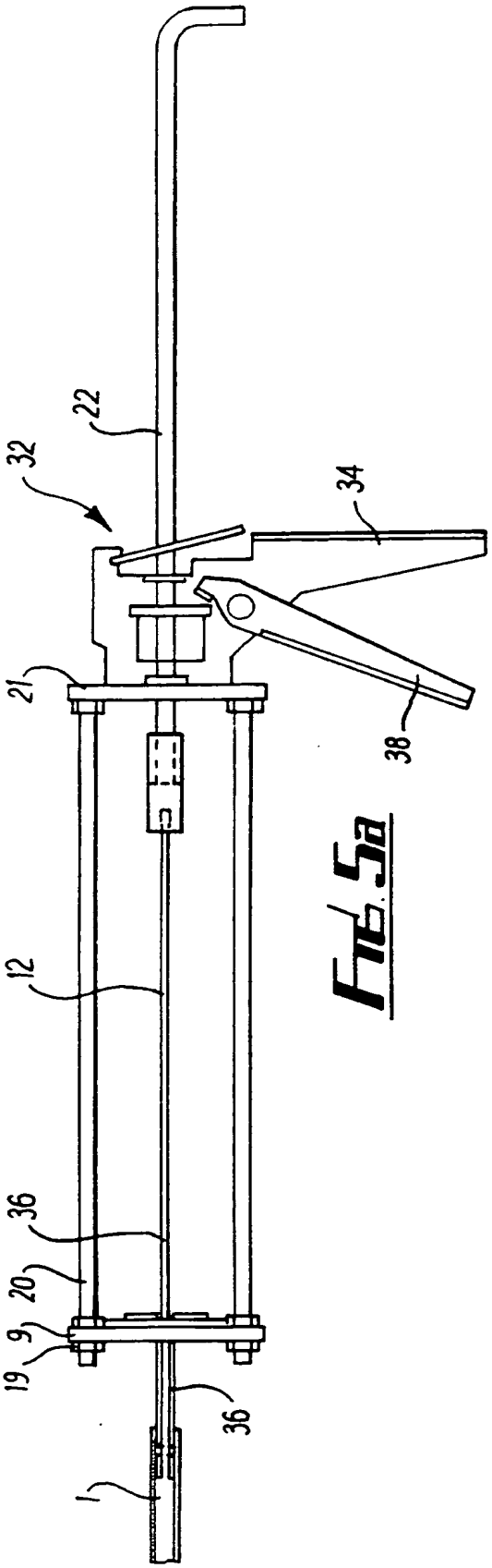

Fig. 5a

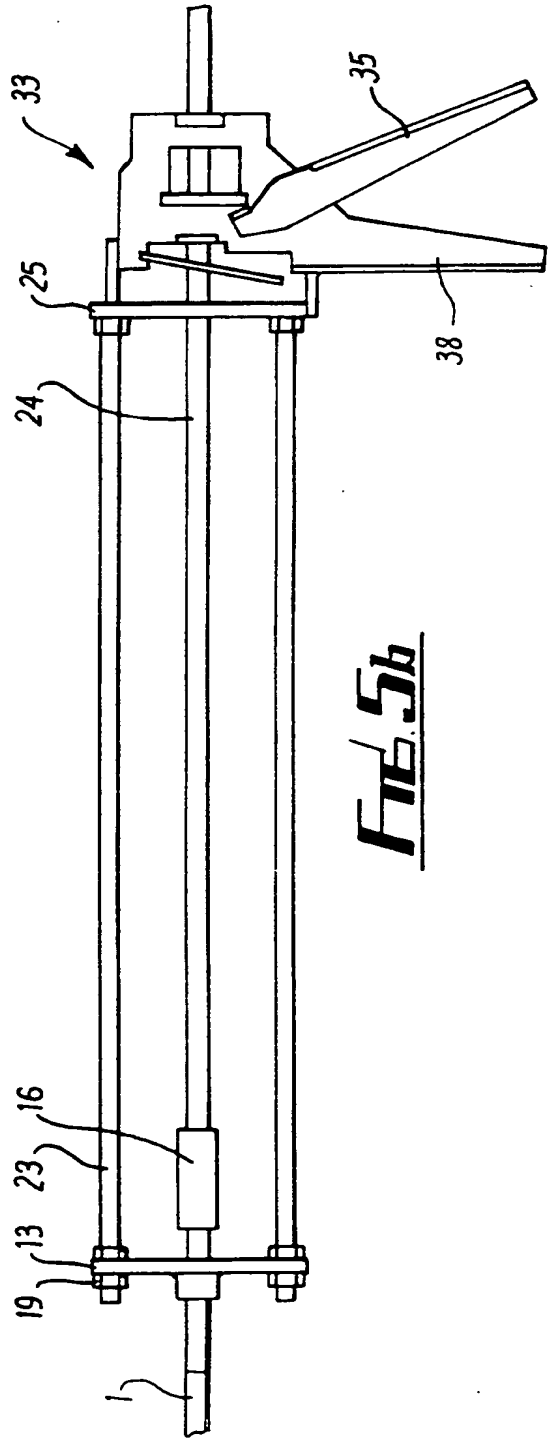

Fig. 5b

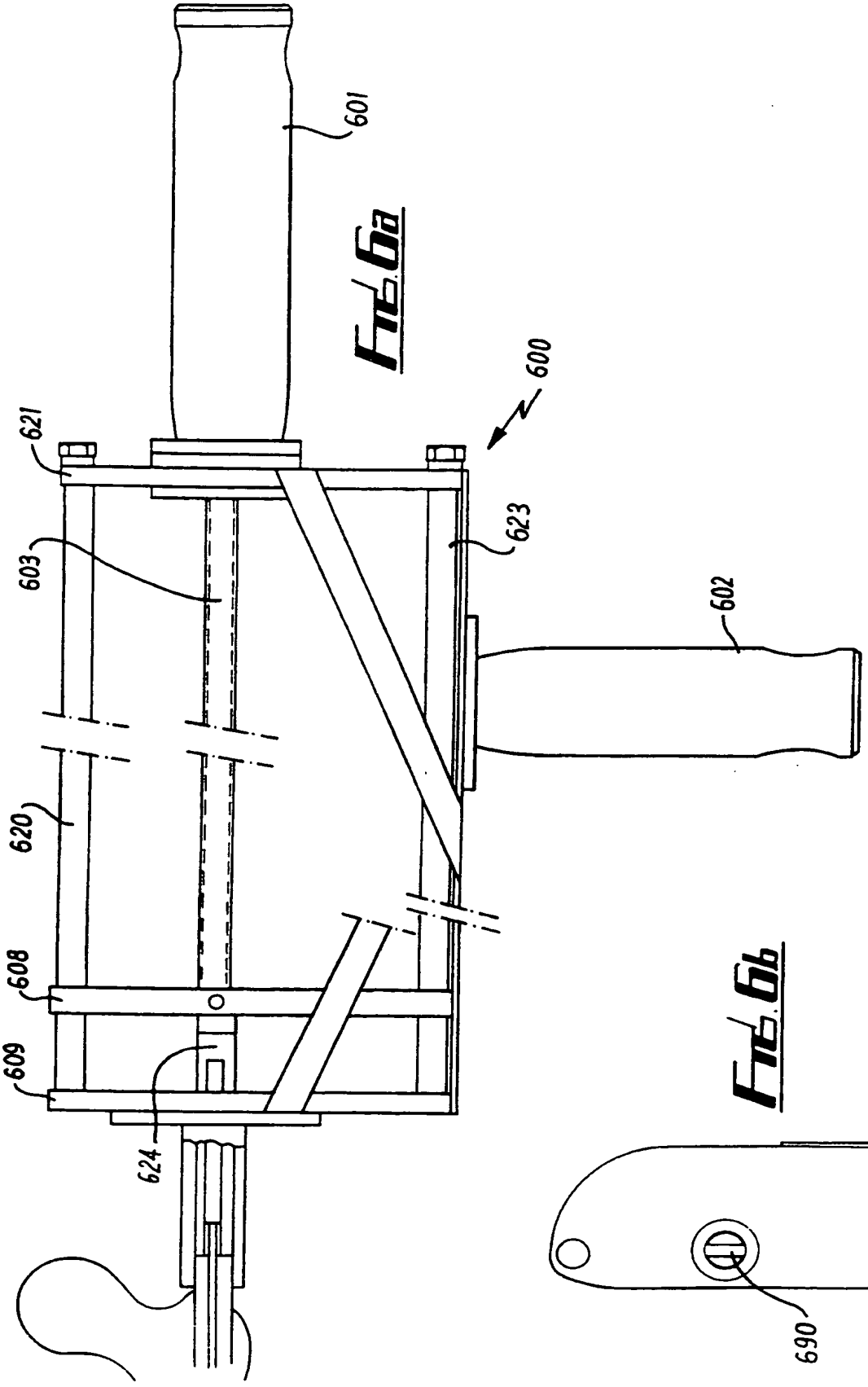

Fig. 6a

Fig. 6b

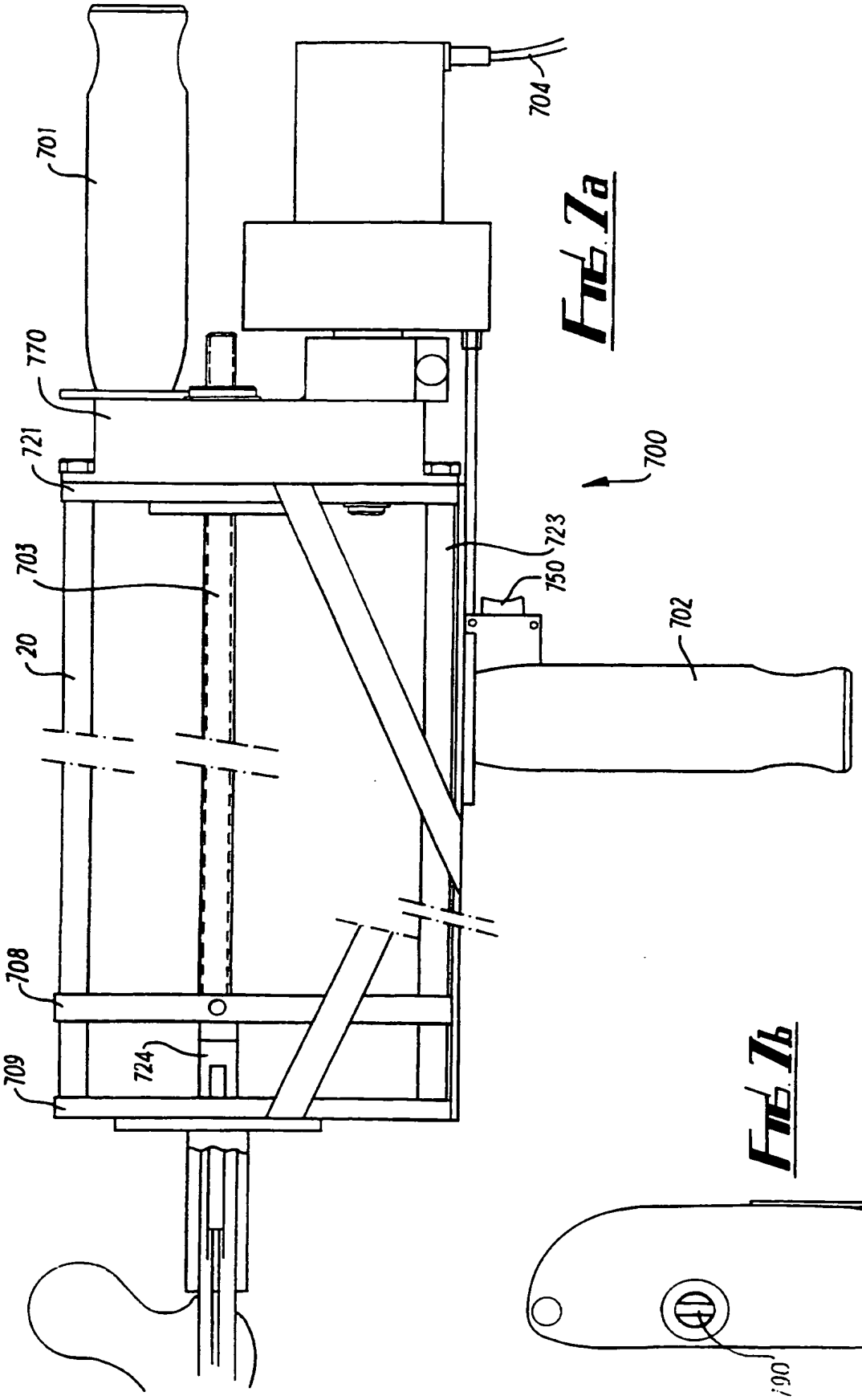

Fig. 7a

Fig. 7b

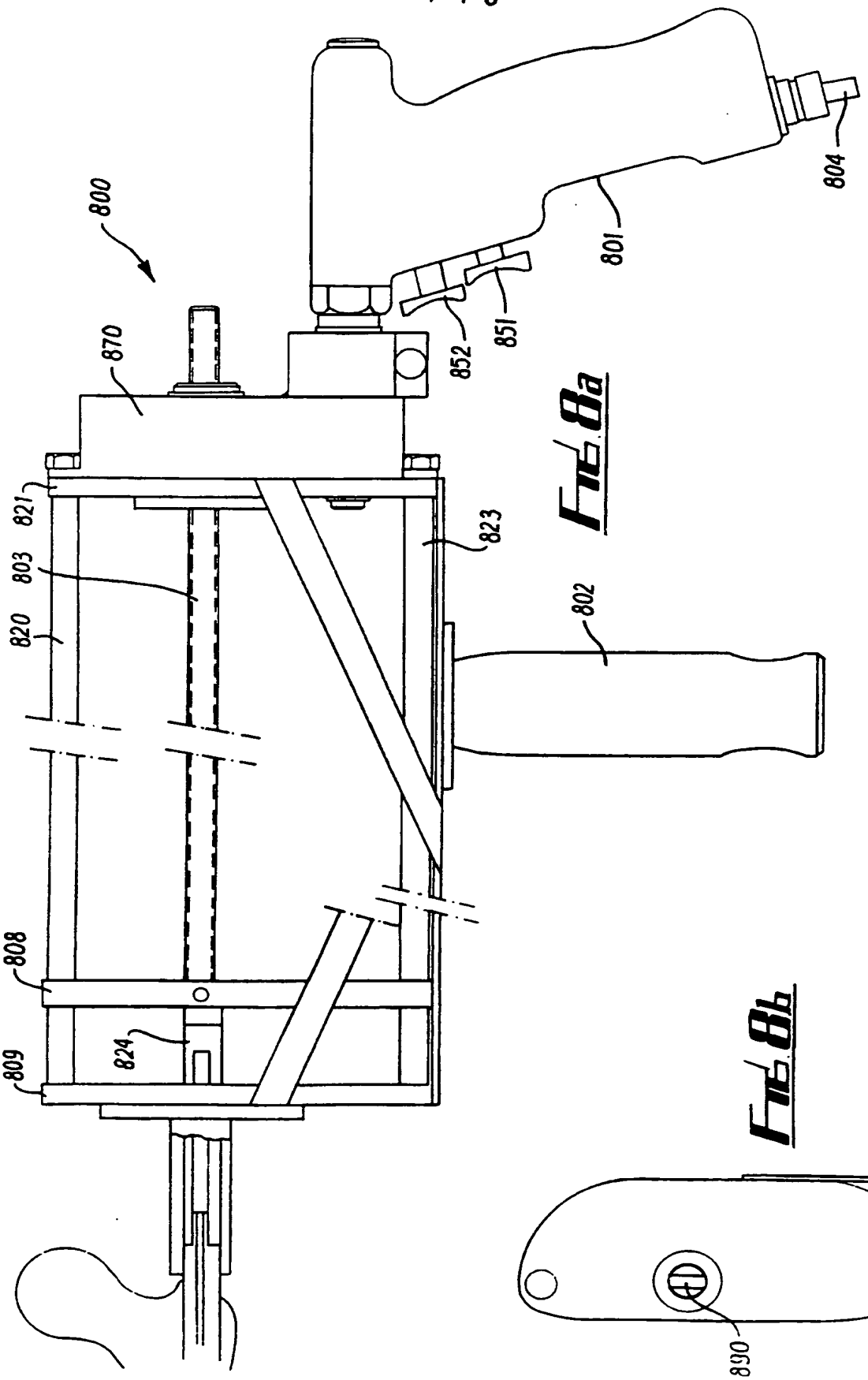

Fig. 8a

Fig. 8b

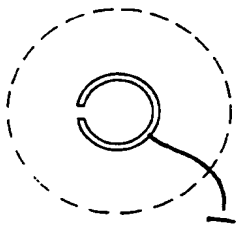

Fig. 9b

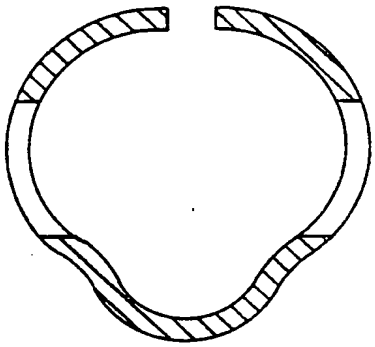

Fig. 10b

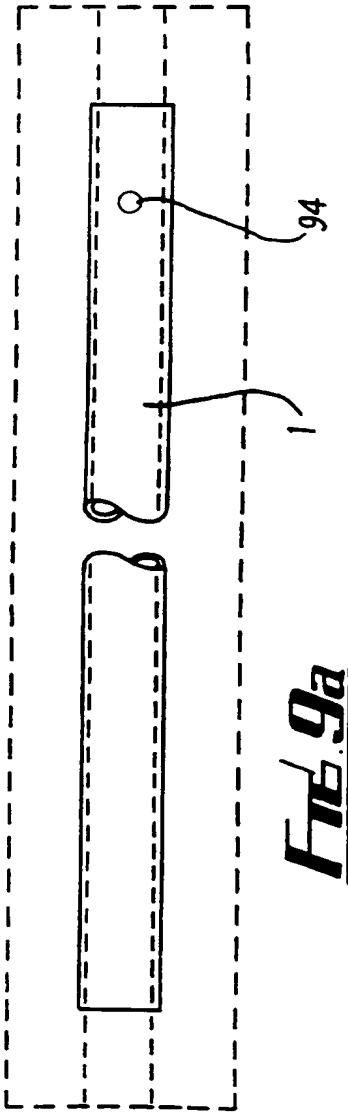

Fig. 9a

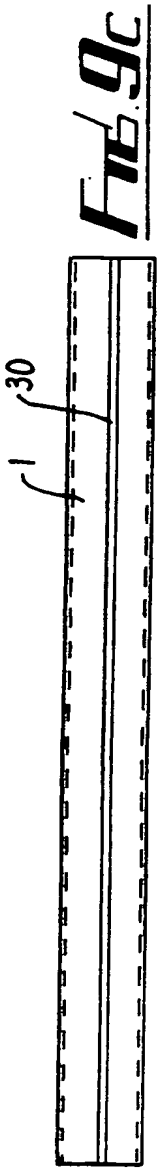

Fig. 9c

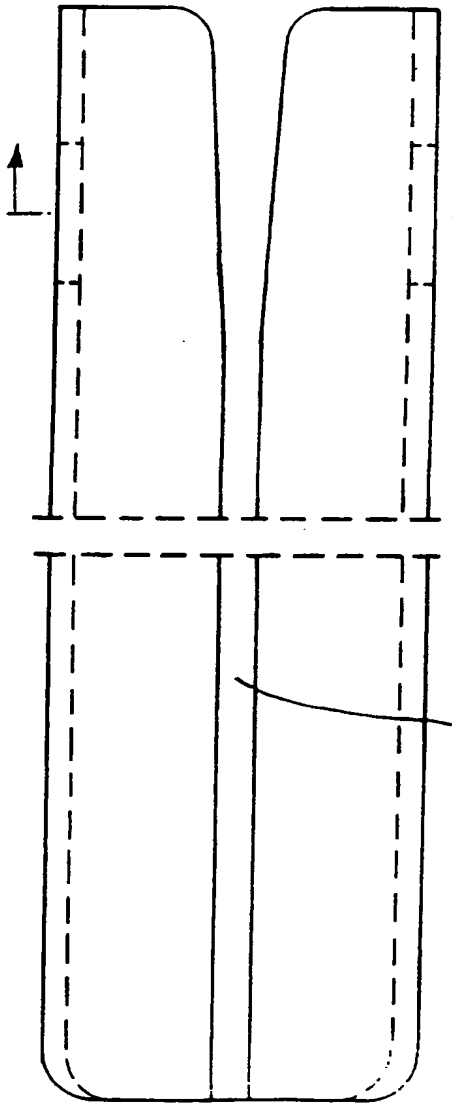

Fig. 10a

Fig.11b

Fig.12b

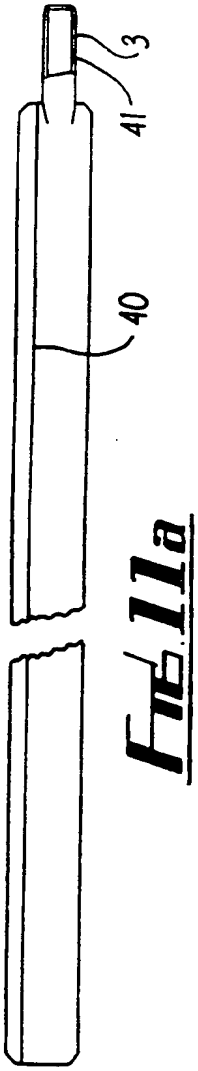

Fig.11a

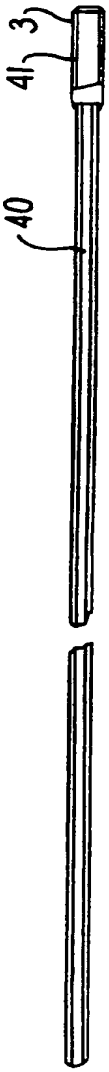

Fig.11c

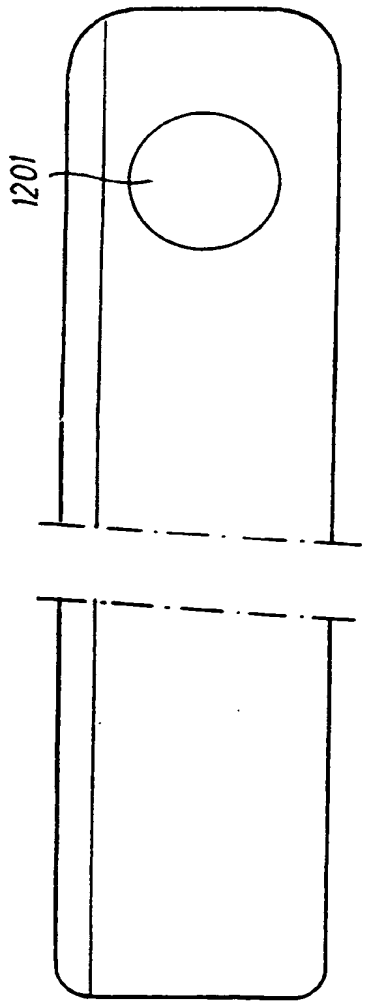

Fig.12a

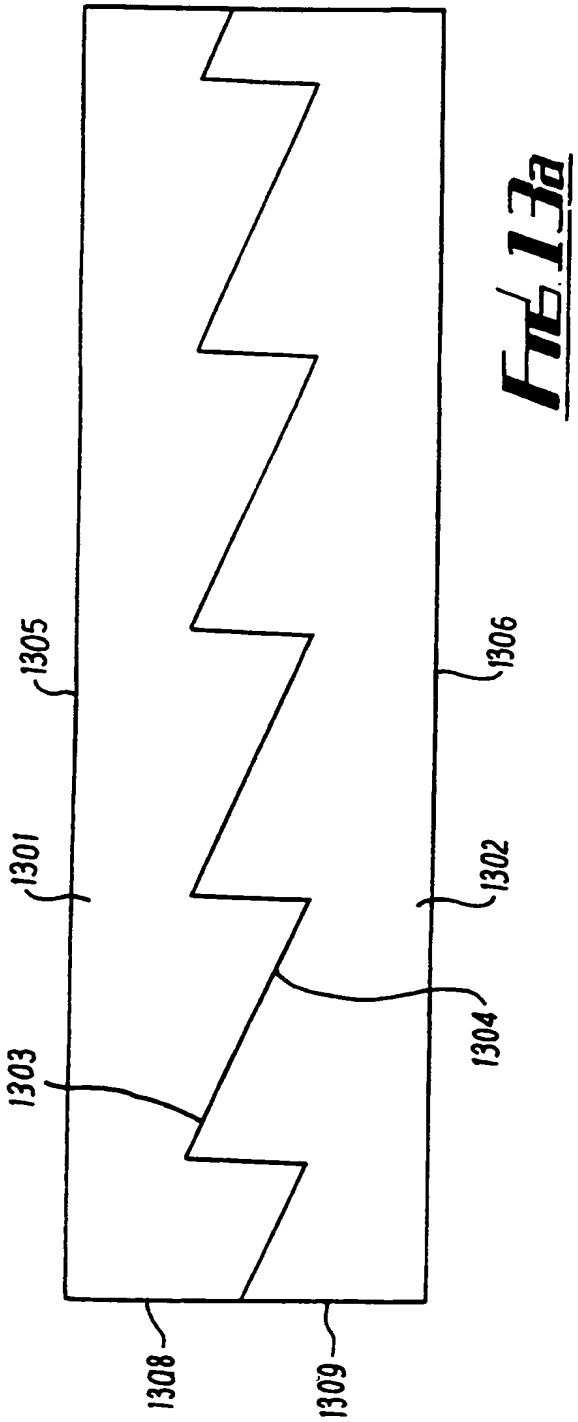

Fig. 13a

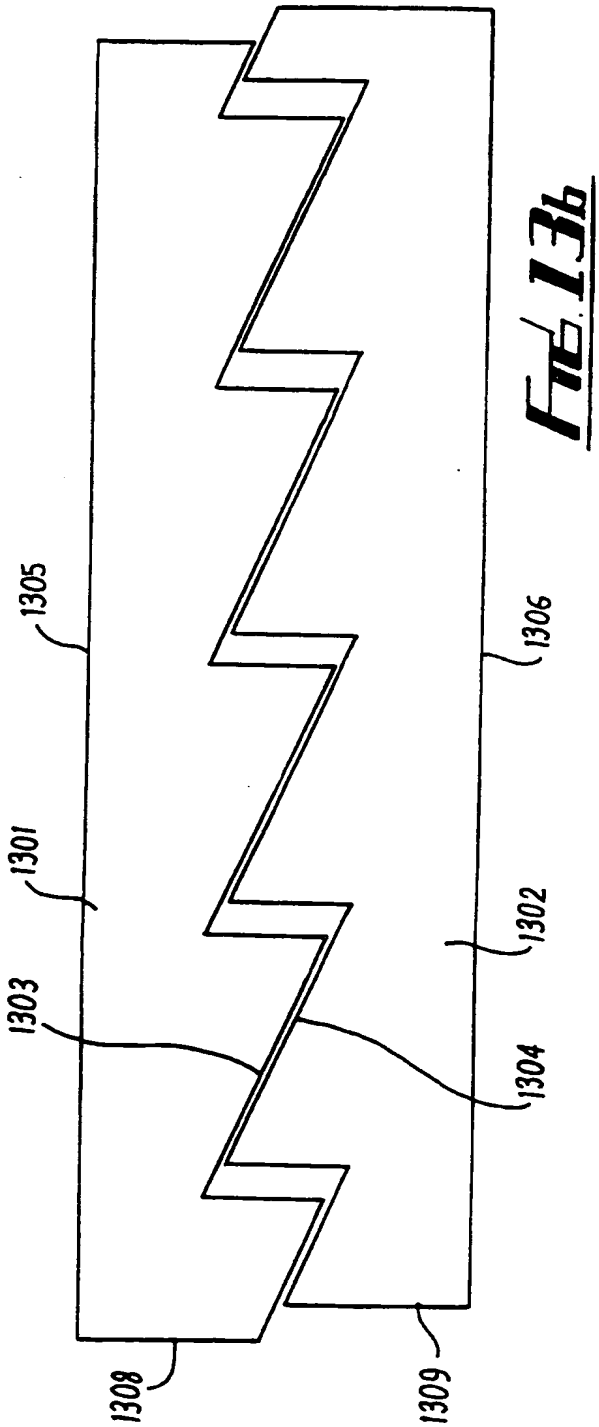

Fig. 13b

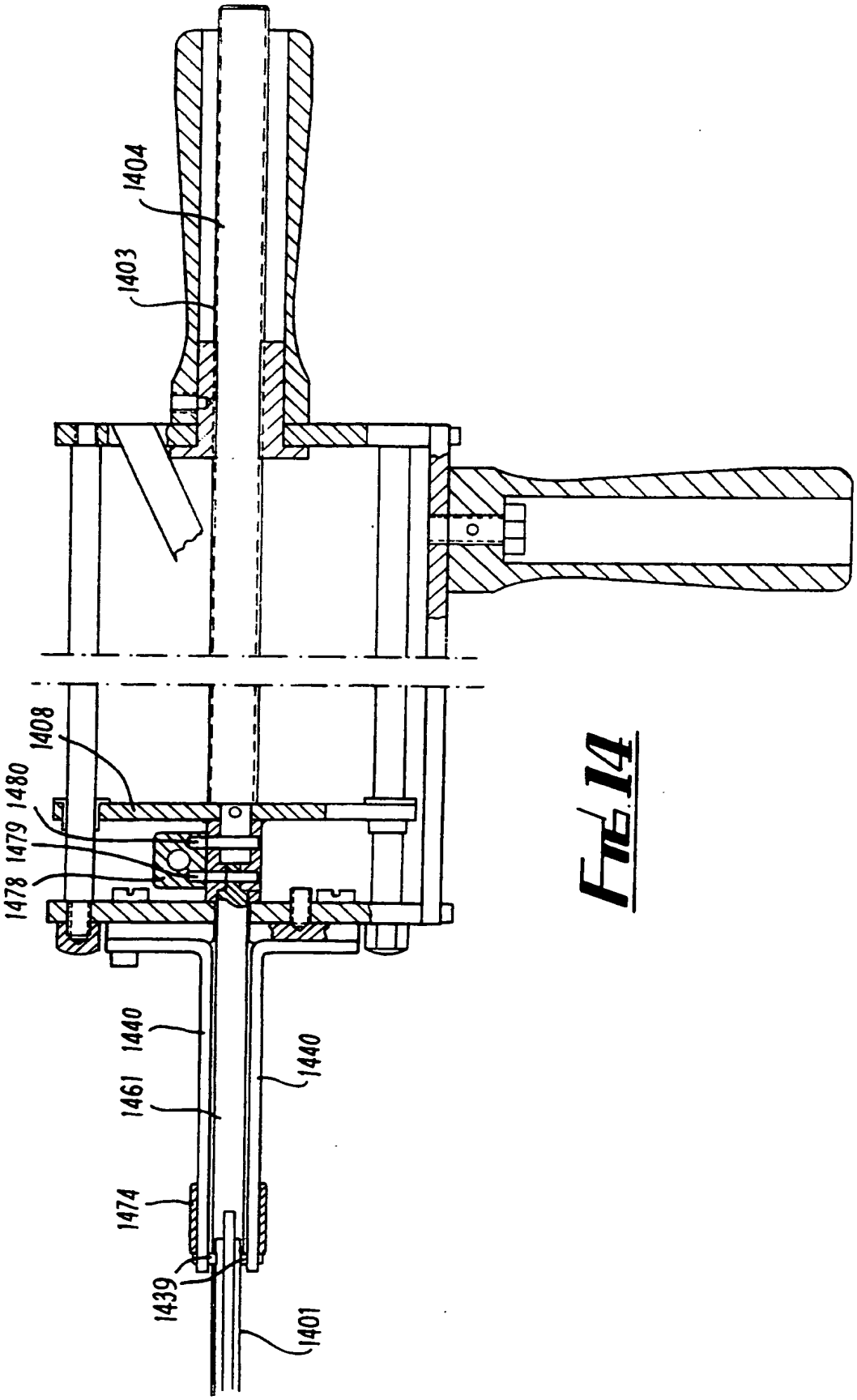

Fig 14

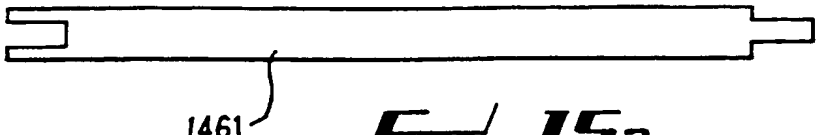

FIG. 15a

FIG. 15b

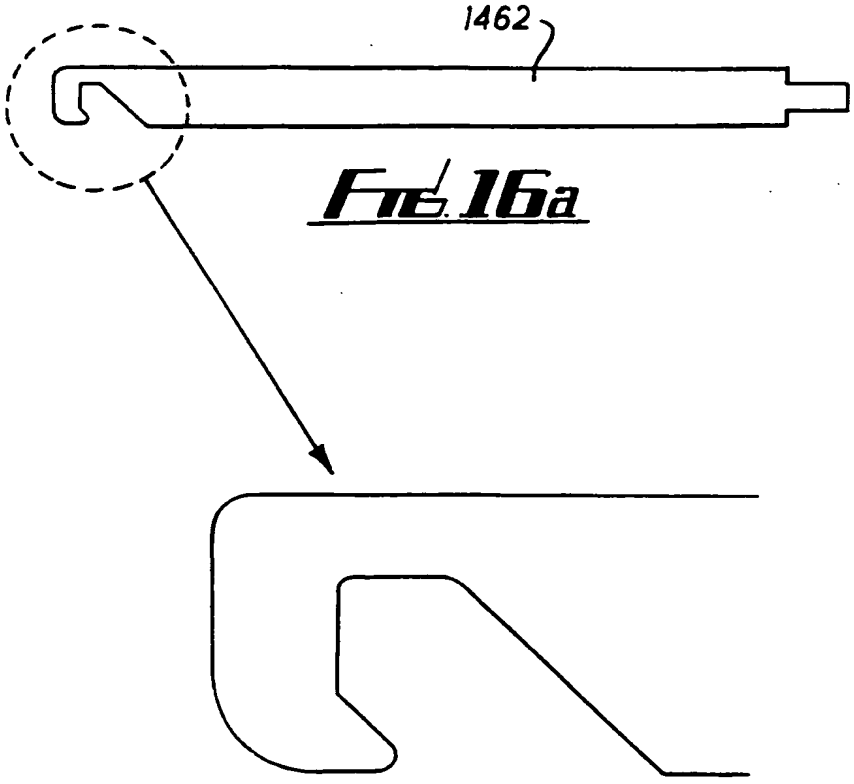

FIG. 16a

FIG. 16b

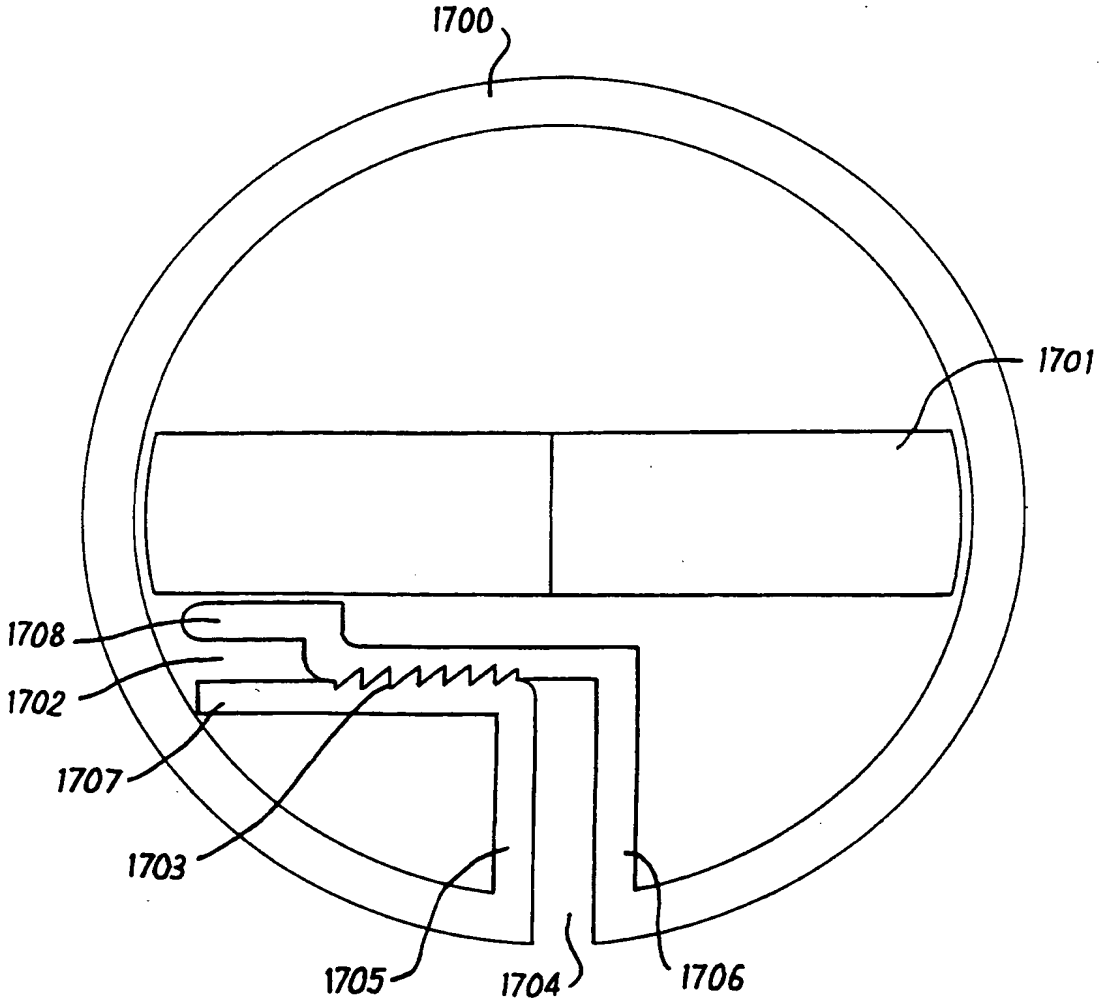

FIG. 17

INTERNATIONAL SEARCH REPORT

Inter. ...al Application No
PCT/GB 93/02390

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 A61B17/58

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 A61B A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE,C,745 873 (POHL) 10 August 1953 see the whole document	1-9, 11-13,15
A	US,A,5 116 335 (HANNON) 26 May 1992 see claim 1; figures	10
A	DE,U,84 00 640 (MECRON) 20 June 1985 see figures 3,4	14
A	US,A,4 854 312 (RAFTOPOULUS) 8 August 1989	
A	WO,A,88 01492 (OFFICE MEDICO CHIRURGICAL INTERNATIONAL) 10 March 1988	
A	US,A,4 531 517 (FORTE) 30 July 1985	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search	Date of mailing of the international search report
10 March 1994	25.03.94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Steenbakker, J

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INTERNATIONAL SEARCH REPORT

information on patent family members

Inte ional Application No
PCT/GB 93/02390

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
DE-C-745873		NONE		
US-A-5116335	26-05-92	NONE		
DE-U-8400640	20-06-85	NONE		
US-A-4854312	08-08-89	NONE		
WO-A-8801492	10-03-88	FR-A-	2606997	27-05-88
		EP-A-	0278963	24-08-88
		US-A-	4911722	27-03-90
US-A-4531517	30-07-85	NONE		